



**Appendix B**

**Economic Impact Estimates –  
High-Global Warming Potential Stationary Source  
Refrigerant Management Program**

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## Summary

The proposed regulation impacts facilities that utilize stationary refrigeration and air-conditioning (R/AC) equipment with greater than or equal to 50 pounds of high global warming potential (GWP) refrigerant. Facilities are categorized into three refrigerant charge size ranges based on the amount of refrigerant contained within individual pieces of equipment used by a facility; greater than or equal to 50 lbs, but less than 200 lbs (small systems); greater than or equal to 200 lbs, but less than 2,000 lbs (medium systems); and 2,000 lbs and greater (large systems). The small systems are typified by commercial roof-top packaged air-conditioners and stand-alone refrigeration units. The medium systems are mainly chillers and centralized refrigeration systems. The large systems are mainly cold storage systems, industrial process chillers, and some centralized refrigeration systems. The resulting characterization of current refrigerant use patterns by facility types and statewide facility number estimates were used to calculate the extrapolated statewide carbon dioxide equivalent (CO<sub>2</sub>E) emissions. For a full description of the affected facilities, see Appendix A (California Facilities and Greenhouse Gas Emissions Inventory).

This appendix presents estimates of the costs and cost savings of the proposed high-GWP stationary source refrigerant management regulation. The economic benefits presented are limited to the cost savings from avoided refrigerant losses. Some energy savings are expected from more optimized operation due to maintaining the proper charge and routine maintenance; however these benefits are not quantified at this time. The economic benefits from mitigated climate impacts from reduced use of high-GWP refrigerants are also not incorporated into these estimates. In these analyses all costs are estimated in constant 2008 dollars.

Costs of refrigerants are expected to rise as hydrochlorofluorocarbon (HCFC, also referred to as ozone depleting substance (ODS)) refrigerants are phased out, and if production and import of hydrofluorocarbons (HFC) are restricted under future legislation. The change in the uses of these refrigerants could only be broadly estimated based on linear interpolation of estimates from the United States Environmental Protection Agency (U.S. EPA) Vintaging Model for 2010 and 2020. The rate of price increases is also unknown. This analysis uses an average of current prices of the refrigerants now in use.

An important aspect of the proposed rule is that the mandated repairs which result in the emissions benefits also result in cost savings that offset a large fraction of the compliance costs. For example, the gross cost to regulated entities for 2020 is estimated to be \$321 million per year. The estimated costs of the proposed regulation are partially offset by annual refrigerant savings of \$194 million based on current refrigerant prices for a net annual cost of \$128 million. The overall cost-effectiveness of the proposal is estimated to be \$8 per metric ton CO<sub>2</sub> equivalent (MTCO<sub>2</sub>E) by the year 2020 when the proposed regulation is fully implemented. This is a conservative estimate in that it does not account for rising refrigerant

prices, energy savings due to optimized system operation, or benefits from mitigated climate impacts.

## Introduction

The Refrigerant Management Program proposed regulation consists of two primary components: 1) facility reporting and leak repair; and 2) refrigerant sale, use, and disposal. Economic costs and benefits analyses were conducted separately for the individual components. The economic analyses reported in this appendix estimate the total costs of the regulation to the regulated community and the fiscal impacts to the enforcement agencies. The economic benefits presented are limited to the cost savings from avoided refrigerant losses.

Costs to regulated facilities and businesses are estimated for the implementation period of 2010 to 2020. The analyses are organized by facilities with large, medium, and small R/AC systems. The analyses provide the costs and benefits by the size of R/AC system and the type of refrigerant used: HFC-only, ODS-only, and both HFC and ODS.

The cost and economic benefits analyses rely on input from the ARB emissions inventory and potential emission reductions outlined in Appendix A, cost and other data from technical literature, input from equipment manufacturers and other stakeholders, and industry surveys. All uncertainties outlined in Appendix A impact the uncertainty of the total cost and economic benefits in this analysis. To evaluate and understand other cost uncertainties, data were collected and reviewed from as many perspectives as possible.

Businesses impacted by this regulation include facilities with R/AC systems with 50 lbs or more of high-GWP refrigerants. These include: grocers, office buildings, meat packers, warehouses used for cold storage, food preparation/processing/service, hospitals and medical facilities, military bases, institutions (schools, universities, laboratories, etc.), hotels and recreational facilities, process cooling. Additional details about these industries and refrigeration and air-conditioning systems are in Appendix A. The proposed regulation also impacts businesses including; R/AC contractors, technicians, reclaimers, distributors, and wholesalers. The impact on the average small, medium, and large facility is projected to be \$230, \$900, and \$2,190 respectively with an overall average impact of \$510 per facility. No change is expected in employment or business competitiveness.

The cost calculation model in this analysis calculates the impact on facilities with average configurations (as outlined in Appendix A): small facilities with approximately 5 systems in the small size range, medium facilities with approximately 5 systems in the medium size range, and large facilities with approximately 2 systems in the large size range. In reality, many “large” facilities that have large sized systems will also often contain medium and small size systems (and likewise, medium facilities will often have smaller systems). It is recognized that facilities with the average configuration do not commonly exist in

practice. The approach taken here is a means of calculating the average impacts of the costs of the rule. The costs of several case studies of real-world facility configurations visited by staff during research for the rule were also calculated and are presented later in this document.

Costs related to automatic leak detection are based on a system that will meet all requirements of the rule and were confirmed through discussions with the manufacturers. The ARB also contracted with ICF International for input into the analysis of the costs of automatic leak detection systems to benefit from their experience in refrigerant management and consulting with the U.S. EPA Vintaging Model development. The primary drivers of uncertainties in the total costs for automatic leak detection are the type of equipment purchased and installation costs.

In reviewing the cost of leak inspections the ARB staff compiled estimates based on two very different perspectives. One perspective was from ICF for in-house or external inspectors and the other was the cost of a leak inspection for enforcement purposes from the ARB, or the air district (the local air quality management district or air pollution control district) inspectors provided by the California Air Pollution Control Officers Association (CAPCOA). The cost varied with ICF cost ranging from \$93 to \$561 per inspection based on two to six hours of inspection time required per facility (on average, 2 to 5 systems inspected either annually or quarterly). The low ICF estimate represents a two-hour in-house inspection and the higher estimate represents a seven-hour inspection by contracted inspectors and includes profits and fees by the contracting company. ARB and CAPCOA estimates ranged from \$195 to \$682 per inspection based on three to six hours per facility (on average, 2 to 5 systems inspected either annually or quarterly). The primary driver of the uncertainty is the assumption of salaries for inspection staff and if salary is based on an in-house, hourly salary or the salary of a contracted certified technician. The costs used in these analyses were \$75 to \$300 per system per year reflecting one to four hours at \$75 per hour.

Leak repair costs are based on research conducted on behalf of the ARB by ICF and discussions with stakeholders. The ARB conducted a survey of refrigeration and air-conditioning service contractors and technicians to validate prior research and discussions.

The estimation of leak repair costs represent 5% of the total annualized leak repair cost (parts, labor, and refrigerant recovery plus the refrigerant amount to recharge the system based on the modeled leak amount) to reflect a five percent real discount rate cost of funds to do the repairs immediately upon the first indication of a leak rather than at a later date and 100 percent of the cost savings due to the total annual refrigerant emission reductions. Under the business as usual (BAU) scenario 100 percent of all leak repair costs are incurred at some point to preserve refrigerated product (or air-conditioning) and R/AC system operations. Based on when the repairs are completed and the total costs are incurred the BAU emissions and BAU average leak rates result. These costs may be incurred immediately after detection of a leak based on best practices or after months or years of deferred maintenance, often with top-offs of refrigerant rather than timely repairs.

The annual discount rate of five percent used in this analysis to ensure consistency with the AB 32 Scoping Plan. In the Scoping Plan's analysis of costs and savings a uniform real discount rate of five percent was used for all measures to estimate the cost of money. This was the first step to annualize the upfront or capital expenditures of all measures.

Because the anticipated result of the proposed rule is the transition from the BAU average leak rate for any specific R/AC group to the post rule implementation average leak rate, the costs and emissions that reflect each scenario are used to estimate cost effectiveness. The BAU leak repair costs reflect 100% of the leak repairs that are currently incurred and 100% of the total estimated BAU emissions. The post-rule implementation scenario leak repair costs reflect 5% of the total cost of leak repairs as the proposed rule does not create a need for leak repair but only requires that leak repairs be completed within 14 days of detection. The emission credit of leak repairs conducted earlier is the transition to the post-rule implementation average leak rate reflecting 100% of the total emission reductions.

The local air districts will be impacted by the need for additional inspection and enforcement resources. These costs are expected to be recovered through the implementation fees imposed on the impacted facilities. The costs to the Air Resources Board (ARB) will include enforcement and inspection costs not assumed by the districts and costs to initiate and maintain a web-based reporting system and database as well as processing and maintaining the annual industry reports.

## **Economic Cost and Cost Savings Estimates (Facility Reporting and Leak Repair Component)**

This section presents the underlying data that were used to estimate the overall cost estimates of the regulation to the regulated community for the program. It includes a discussion of the input data as well as of each key element of the program including implementation fee, reporting and recordkeeping costs, automatic leak detection system annual audits and R/AC system leak inspections, automatic leak detection system capital and operating costs, and leak repair costs.

**Input data:** Economic costs and cost savings of the regulation are calculated using the emissions inventory data and projected emission reduction estimates provided in Appendix A and additional economic input variables discussed below. Estimated costs are tiered by system size to reflect different workload (e.g., monitoring, inspection, etc.) demands. The proposed rule provides for staging the implementation fee and reporting requirements depending on the system size: facilities with large systems commence in 2010; facilities with medium size systems (but no large sized systems) would begin in 2012. Facilities whose R/AC systems are no larger than 50-200 pounds (i.e., they do not have medium or large systems) will not be subject to either the reporting or annual implementation fee requirements of the rule although they will be required to conduct annual inspections of their R/AC systems and to maintain records of their repairs and refrigerant transactions and

have those records available for enforcement inspectors. The refrigerant leak detection and monitoring, leak repair, and recordkeeping provisions all commence in 2010 for all applicable systems.

The cost related input factors used in the economic model, discussed below and listed in Table 1, are based on literature review, a survey of refrigeration and air-conditioning service contractors, certified technicians, and discussions with stakeholders. Although the annual implementation fee for facilities with small systems is quoted as \$0, we are considering inclusion of a one-time registration fee for these facilities. The costs were calculated in this appendix with \$0 as shown in Table 1.

**Table 1:** Economic estimates input factors

	<b>Facilities with small systems</b>	<b>Facilities with medium systems</b>	<b>Facilities with large systems</b>
Annual implementation fee (per facility)	\$0	\$170	\$370
Annual reporting and recordkeeping costs (per facility)	\$116	\$449	\$465
Automatic leak detection annual audit, quarterly inspection, or annual inspection costs (per system)	\$75 per R/AC system	\$300 per R/AC system	\$150 per R/AC system
Automatic leak detection capital costs (per system)	N/A	N/A	\$8,130 per system (capital and installation cost) annualized over 12 years (\$917/year at 5% real discount rate)
Automatic leak detection operational costs (per system)	N/A	N/A	\$720
Leak repair costs (base cost per leaking system) *	\$45	\$78	\$122
Post-repair refrigerant recharge (per leaking system)	4 lbs	23 lbs	150 lbs

\*repairs quoted as 5% real discount rate

Table 2 presents the costs to ‘average’ facilities. Implicit in Table 2 are the following assumptions: Evacuation equipment, already required by federal rules for ODS system repairs, is already available and could be employed for recovery of all refrigerants. The proposed rule is not anticipated to result in additional costs for evacuation equipment. For all labor estimates an hourly labor rate of \$75 is used. The average facility with small systems has approximately 5 systems, the average facility with medium systems has approximately 5 systems, and the average facility with large systems has approximately 2 systems (number of systems rounded for clarity, actual average number used in calculations). Repair costs represent 5% of the cost of making the repair (parts, labor, and refrigerant recovery plus the refrigerant amount to recharge the system based on the modeled leak amount) to reflect the real discount rate cost of funds to do the repairs immediately upon the first indication of a leak rather than at a later date. Costs also include the percent of systems that leak in a given year as described in Appendix A (approximately 30% of large systems, 26% of medium systems, and 19% of small systems will leak and require repairs).

**Table 2** Example costs to average facilities

	Facilities with small systems	Facilities with medium systems	Facilities with large systems
Annual implementation fee	\$0	\$170	\$370
Annual reporting and recordkeeping costs	\$116	\$449	\$465
Automatic leak detection annual audit, quarterly inspection, or annual inspection costs	\$390	\$1,640	\$290
Automatic leak detection capital costs	N/A	N/A	\$15,950 annualized over 12 years (\$1,800/year)
Automatic leak detection operational costs	N/A	N/A	\$1,410
Leak repair costs	\$60	\$130	\$400
<b>Total gross cost</b>	<b>\$560</b>	<b>\$2,430</b>	<b>\$4,570</b>
Refrigerant savings	\$330	\$1,540	\$2,380
<b>Total net annual costs</b>	<b>\$230</b>	<b>\$900</b>	<b>\$2,190</b>

- Annual implementation fee – The annual implementation fees would be assessed to implement the rule and compensate the enforcement agency for their staff training expenses, reporting system development, and inspection and recordkeeping time. The proposed fee amounts are based on input from CAPCOA<sup>1</sup> and the ARB Enforcement Division studies of their time and materials needed to conduct inspections. The time needed includes pre-inspection time for facility records review; on-site equipment inspection; review of equipment service records and leak repair records; review of refrigerant purchase, use, and shipping records; travel planning; and report writing.
- Reporting and recordkeeping costs – Each facility will be required by the regulation to maintain records of their repairs, refrigerant use and purchases, etc. The facilities with large and medium size systems will be required to report their leak inspections, service, refrigerant leak repairs, and refrigerant consumption by device or system. Additionally facilities will be required to report an annual summary of refrigerant purchased, charged into systems, and recovered from systems. Facilities with only small systems will need to retain the records and have them available for ARB or local air district inspectors. Facilities with only small systems are required to only maintain records; annual reports are not required. The values in the calculations assume that the ARB will initiate and maintain a web-based reporting system and database. The reporting and recordkeeping costs reflect time costs for the facility to maintain records and submit a periodic report.

Many facilities, especially those with large systems already have a process in place for tracking repairs, refrigerant use, and leak rates. The ARB is developing a system whereby the reports will be efficiently transferred to a centralized database for access by ARB and, where appropriate, the air

<sup>1</sup> Memo from CAPCOA to Anthony Andreoni, November 4, 2008

districts. For large facilities it is estimated to take 15 minutes per system leak to record leaks, 15 minutes per month per monitored system to maintain records of the automatic leak detection system, and 10 minutes once per year to submit the report. For medium facilities it is estimated to take 15 minutes per system leak to record leaks, 15 minutes 4 times per year to maintain records of the leak inspections, and 10 minutes once per year to submit the report. For small facilities it is estimated to take 15 minutes per system leak to maintain repair records and 15 minutes once per year for each system to maintain the leak inspection records. The \$75 labor rate was used in these calculations.

The total reporting and recordkeeping costs per facility are outlined in Table 1. Using large systems as an example the Table 3 outlines how these costs are calculated.

**Table 3:** Reporting and recordkeeping costs per large facility

Large Systems	Minutes	Occurrences per Year	Systems / Units	Percent Leaking Systems	Hours
Record Keeping - Recording Leaks	15	(variable by probability of leak)	2	29.8%	0.1
Recordkeeping Auto Detection System Audit	15	12	2		5.9
Reporting	10	1			0.2
Total Hours					6.2
Total Costs (@ \$75 / hour)					\$465

- Automatic leak detection annual audit, quarterly inspection, or annual inspection costs – Large R/AC systems will be required to use an automated system to detect leaks (usually a continuous monitor, but other automatic leak detection systems will be allowed). The medium size systems will be required to be inspected for leaks quarterly and the small systems annually. The automatic leak detection annual monitoring costs reflect the costs for audits of the automatic leak detection monitoring system and for the quarterly or annual inspections. It is estimated that a large system leak detection system audit will take two hours per system to complete, an inspection of a medium system will take one hour per system each quarter, and a small system inspection will take one hour per system once per year. The \$75/hour labor rate was used in these calculations.

The total automatic leak detection annual audit and leak inspection costs are outlined in Table 1. Table 4 outlines how these costs are calculated.

**Table 4:** Automatic leak detection system audit and leak inspection costs per system

Leak Inspection	Hours	Times per Year	Total Hours per System	Total Cost per System
Automatic Leak Detection Audit	2	1	2.0	\$150
Medium Sized Leak Inspections	1	4	4.0	\$300
Small Sized Leak Inspections	1	1	1.0	\$75

- Automatic leak detection capital and operational costs
  - Installation cost – The installation cost data reflects a best estimate of the capital cost to purchase an automatic leak detection system based on market studies conducted for this analysis<sup>2</sup>. The capital costs are estimated at \$6,100 plus \$2,030 to install the system (total of \$8,130) annualized over a twelve-year projected life of the monitoring system at a 5% real discount rate (\$917/year). The costs were discussed with several manufacturers and are representative of reliable monitoring systems and are typical of quotes from several manufacturers. The cost is based on an average monitoring system with a central control panel and eight distributed input sensors. Each monitoring systems may use one to many sensors; many monitoring systems types are capable of handling up to 16 sensors per controller. The average monitoring system modeled would monitor the possible leaks on one refrigeration or air-conditioning system. Although one automatic leak detection system per R/AC system was modeled, each facility will likely have a somewhat different configuration. In some applications a single monitoring system may be able to monitor for leaks on one or on several R/AC systems, depending on configuration and sensor design and placement and the design of the R/AC systems. Facilities may also choose to configure the monitoring systems to monitor zones of the facility; i.e. one system may monitor the equipment room while another monitoring system may monitor for leaks in the evaporators, etc.
  - Monitoring cost per year – The annual costs to operate an automatic leak detection and monitoring system assume a system with a central control panel and eight distributed input sensors. The annual maintenance costs assume annual system calibration, replacement of filters, and other routine maintenance estimated at \$90 per monitoring point<sup>2</sup> (\$720 for a monitoring system monitoring 8 points).
- Leak repair costs – Leak repair costs in Table 1 are divided into three ranges. It is assumed that a small system (low range cost) will require lesser repairs while a medium and large system will require progressively more extensive repairs when a leak occurs. Leak repair costs are two-fold: the base cost of making the repair and the refrigerant needed to recharge the system to its

<sup>2</sup> ICF to ARB, October 21, 2008

nominal operating charge. Table 5 shows that the base repair costs (labor, parts, and refrigerant recovery) are \$900, \$1,550, and \$2,450 for low, medium, and high cost repair scenarios projected for the small, medium, and large systems. The base costs include 8, 12, and 16 hours of labor at \$75/hour; \$100, \$300, and \$600 in parts; and \$200, \$350, and \$650 for refrigerant recovery for small, medium, and large systems respectively.<sup>3, 4</sup> The change in refrigerant needed to recharge the system following a repair is calculated from the modeled average target leak amount per system size and a refrigerant cost of \$11 per pound. The target leak amount represents a realistic and achievable reduction in leaks projected as a result of the leak detection and monitoring provisions of this rule. Refrigerant savings are the difference between the BAU leakage and the target leak amount (Table 6). The recharge for large systems is, on average, about 150 pounds per system per year (see Appendix A for more details), down from 260 pounds based on the BAU leak rate; a savings of \$1,212. Since the leaking systems eventually need to be repaired to continue to operate without regard to this rule, the repair costs (both base costs and cost of the refrigerant to recharge the system after the repairs) in the model are based on the real discount rate cost of funds (estimated at 5% of the cost of the repair) to do the repairs immediately upon the first indication of a leak rather than at a later date when the leak affects the operation of the system.

**Table 5:** Base repair costs

	<b>Labor hours / cost (@ \$75 per hour)</b>	<b>Parts</b>	<b>Refrigerant recovery</b>	<b>Total parts, labor, and recovery</b>	<b>Total at 5% real discount rate</b>
Small systems	8 hrs / \$600	\$100	\$200	\$900	\$45
Medium systems	12 hrs / \$900	\$300	\$350	\$1,550	\$78
Large systems	16 hrs / \$1,200	\$600	\$650	\$2,450	\$122

**Table 6:** Leak repair refrigerant costs and savings

	<b>BAU average annual refrigerant leak (lbs)</b>	<b>Target average annual refrigerant leak (expected amount needed to recharge following repair) (lbs)</b>	<b>Refrigerant savings (lbs)</b>	<b>Refrigerant cost savings (@ \$11 / lb)</b>
Small systems	10	4	6	\$64
Medium systems	49	23	26	\$282
Large systems	260	150	110	\$1,212

- **Refrigerant cost** – The refrigerant cost estimate is based on discussions with stakeholders. The cost is estimated at \$11 per pound. The \$11 cost is derived from the average of a suite of refrigerants currently in common use. The cost of the individual refrigerants currently varies from \$4.50 to \$23.00 per pound. All costs and savings are stated in constant 2008 dollars.

<sup>3</sup> ICF to ARB November 10, 2008

<sup>4</sup> ARB technician survey results

- New facilities and systems per year – The growth of the number of facilities and systems was estimated at 1% per year

**Calculations:** Costs of the rule are calculated for calendar years 2010 through 2020 (the year 2020 is summarized in Table 7. Since the rule is not expected to take effect until the middle of 2010, the costs for that year are calculated for ½ of a calendar year. New facilities and systems are assumed to exist for the entire year they enter service and costs are calculated for a given year from the beginning of the year.

**Table 7:** Statewide annual cost of the rule 2020

	Annual cost (HFC plus ODS systems) (\$ millions)	HFC systems only (\$ millions)
<b>Recurring Annual Costs</b>		
Implementation	\$16.4	\$12.4
Reporting and recordkeeping	\$57.0	\$45.6
Leak inspection	\$186.8	\$149.4
<b>Automatic leak detection and monitoring</b>		
Capital and installation cost	\$20.3	\$16.2
Annual maintenance	\$15.9	\$12.7
<b>Repair*</b> (labor, parts, and refrigerant recharge)	\$25.0	\$20.0
<b>Gross cost</b>	\$321.4	\$256.4
<b>Refrigerant savings</b>	\$193.9	\$155.1
<b>Net cost</b>	\$127.5	\$101.3
<b>Emissions reductions</b>	15.4 MMTCO <sub>2</sub> E	12.4 MMTCO <sub>2</sub> E
<b>Cost-effectiveness</b>	\$8/MTCO <sub>2</sub> E	\$8/MTCO <sub>2</sub> E

\*repairs quoted as 5% real discount rate cost of funds (see text for details)

- Recurring annual costs – Facilities will incur annual costs for inspections and implementation, reporting and recordkeeping, and annual and quarterly leak inspections or annual leak detection monitoring system audits. The facility will pay an annual implementation fee to the ARB which will be used by the enforcing agency (either the local air pollution control district or the ARB) to recoup their implementation, inspection, and enforcement costs. Existing facilities with large and medium systems will begin incurring these implementation fees in 2011 (for the year 2010). Facilities with small size systems, in this analysis, are not subject to the annual implementation fee, although a one time registration requirement and implementation fee is being evaluated for the facilities with small systems. The reporting and recordkeeping costs and leak inspection or annual leak detection system audits will be costs incurred by the facility to comply with the provisions of the rule. The recordkeeping and leak inspection/monitoring system audit provisions will go into effect for all facilities when the rule goes into effect. Facilities with only small systems will not have to file the annual report. The

implementation fees and reporting and recordkeeping costs are calculated as a cost for each per facility regardless of the number of refrigeration and air-conditioning systems at that facility. The leak inspection or leak detection system audits are calculated as a cost per system at the facility (i.e. if a facility has 3 refrigeration systems it will incur a single annual implementation fee that covers the entire facility, the single reporting and recordkeeping cost also covers the entire facility, and 3 times the system leak inspection or leak detection system audit costs listed in Table 1 [once for each system]).

Equation 1: statewide recurring annual costs

$$C_a = N_f \times (F_a + R + L_c \times N_s)$$

$C_a$  = statewide recurring annual costs

$N_f$  = number of affected facilities

$F_a$  = annual implementation fees (inspections, etc.) per facility

$R$  = reporting and recordkeeping expenses per facility

$L_c$  = annual and quarterly leak inspection or annual leak detection monitoring system audits

$N_s$  = number of systems per facility

- Automatic leak detection and monitoring costs – Facilities with large R/AC systems will be required to have a mechanism for automatic leak detection and monitoring of each large system. This will primarily be a continuous monitoring system measuring the presence of refrigerant in the air surrounding the components of the R/AC system, but other continuous leak detection mechanisms and procedures will be allowed.

The automatic leak detection system requirements of the proposed regulation can be met by a direct system that detects the presence of refrigerant in ambient air or an indirect system that interprets parametric measurements of the R/AC system that would indicate a refrigerant leak. It is assumed that a direct system would be more expensive since it requires considerable monitoring of the refrigerant in the system and modeling (including design and testing of the model for the specific system monitored) to adequately and promptly indicate the presence of a leak. The analysis focuses on direct systems for a representation of the likely costs for an automatic leak detection system. In some cases the indirect (parametric monitoring) may be more feasible, depending on the R/AC system design (systems with outdoor components, etc).

The facilities will incur capital costs associated with the installation of an automatic leak detection system and its operation. The capital costs for a continuous system to monitor the presence of refrigerant leaked into the air surrounding the components of the R/AC system are estimated at \$8,130 capital and installation costs annualized at a 5% real discount rate over a twelve-year projected life of the monitoring system (\$917 per year). This is calculated at the system level (i.e. a facility with multiple large systems will

incur these costs on each system). The costs were modeled as one monitoring system per R/AC system as an average scenario recognizing that the monitoring systems at a facility may be configured in other ways, as discussed on page 9.

The typical monitoring system requires that it be maintained annually. The maintenance costs include the replacement of filters and/or calibration of the sensors, depending on the design of the system. These costs are typically approximately \$90 per monitoring point per year (\$720/year for the average 8 point monitoring system).<sup>5</sup>

Equation 2: annual automatic leak detection and monitoring costs

$$C_m = N_f \times (N_s \times (M + I))$$

$C_m$  = automatic leak detection and monitoring costs

$N_f$  = number of affected facilities

$N_s$  = number of systems per facility requiring automatic leak detection systems

$M$  = annual cost of maintaining the system

$I$  = capital cost to install a system (annualized)

- Leak repair costs – All facilities/systems will be subject to the leak repair requirements of the regulation in mid-2010 when the regulation is expected to go into effect. The repair costs are calculated as the cost of the repair (labor and parts) and the refrigerant to recharge the system to replace the refrigerant lost in the leak. Since the leaking systems will have to be repaired to continue to operate without regard to this rule, the repair costs in the model are based on the cost of funds (estimated at 5% of the cost of the repair) to do the repairs immediately upon the first indication of a leak rather than at a later date when the leak begins to affect the operation of the system.

Equation 3: annual leak repair costs

$$C_f = N_s \times L_s \times (C_{fa} + \text{Ref}) \times 5\%$$

$C_f$  = leak repair cost

$N_s$  = number of affected systems

$L_s$  = percent of systems leaking

$C_{fa}$  = repair cost

Ref = cost of refrigerant to recharge the system

- Statewide gross annual cost – The gross cost is the sum of all costs incurred in a given year.

Equation 4: statewide gross annual costs

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<sup>5</sup> ICF to ARB October 21, 2008 and discussions with equipment manufacturers

$$C_g = C_a + C_m + C_f$$

$C_g$  = statewide gross annual costs

$C_a$  = statewide recurring annual costs

$C_m$  = automatic leak detection and monitoring costs

$C_f$  = leak repair cost

- Statewide net annual cost – The net annual cost is the gross cost minus the savings due to less refrigerant used because the leaks are repaired earlier as compared to the business as usual scenario, resulting in reduced refrigerant leaked.

Equation 5: statewide net annual costs

$$C_n = C_g - (L_{r1} \times P_r)$$

$C_n$  = statewide net annual costs

$C_g$  = statewide gross annual cost

$L_{r1}$  = reduced refrigerant need per year

$P_r$  = refrigerant price

Although some energy savings are expected from more optimized operation due to maintaining the proper charge and routine maintenance; these benefits are not quantified at this time and not included in Equation 5.

- Cost-effectiveness (C/E) – The cost-effectiveness is the ratio of the net costs to the emission reductions ( $L_{r2}$ ) expected due to the enhanced leak detection and repair requirements of the rule, in dollars per metric ton of CO<sub>2</sub>E (\$ / MTCO<sub>2</sub>E).

Equation 6: cost-effectiveness (C/E)

$$C_e = C_n / L_{r2}$$

$C_e$  = cost-effectiveness (\$ / MTCO<sub>2</sub>E)

$C_n$  = statewide net annual costs

$L_{r2}$  = reduced leak per year in metric tons of CO<sub>2</sub>E

In 2020 when the rule is in full effect the statewide net annual costs are expected to be approximately \$127.5 million (\$24.7 million, \$65.1 million, and \$37.7 million for large, medium, and small facilities) with reduced emissions of 15.4MMTCO<sub>2</sub>E (1.9, 9.8, 3.8 MMTCO<sub>2</sub>E for large, medium, and small facilities) and a cost-effectiveness of approximately \$13/MTCO<sub>2</sub>E, \$7/MTCO<sub>2</sub>E, and \$10/MTCO<sub>2</sub>E for large, medium, and small facilities respectively with an overall average of \$8/MTCO<sub>2</sub>E.

The costs and cost-effectiveness for any given facility will be dependent on the size, design, and number of systems at the facility and the quality of maintenance and repair. A facility that quickly locates leaks and repairs them will reduce the amount of refrigerant leaked when a leak occurs and save more refrigerant and therefore, receive more of the cost benefits than a facility that is not as vigilant. It will also be more cost effective for a facility to construct their R/AC system and make repairs using quality parts so that leak occurrences are minimized.

## Example Case Studies

The analysis of potential emission reductions and costs is based on the resulting average leak rate for an entire population of R/AC systems and is based on the resulting annual emissions as compared to the exact emissions that would result from a single refrigerant leak incident. As an example, a R/AC system with a refrigerant charge of 2,000 pounds that has a leak at a 10% refrigerant leak rate would leak 200 pounds of refrigerant over a one-year period if it were not repaired. If detected promptly and repaired within 14 days of detection the actual emissions from this specific leak would be reduced to less than eight pounds – less than ½ of one percent of the full charge. This example would be included in an average over many systems on an annualized basis to reflect the total cost and potential emission reductions.

Several scenarios have been generated to illustrate how industry may be impacted by the proposed regulation. Although the rule is expected to go into effect in mid-2010, there will be a phase-in period. The case studies are based on the year 2020 because it allows for comparison with the statewide emission reduction targets specified in AB 32 and because all aspects of the rule will be in effect at all facilities subject to the regulation. These scenarios are described in the bullets that follow and then summarized in Table 8. Since it is assumed that the leaking systems will have to eventually be repaired to continue to operate without regard to this rule, the repair costs in the model are based on the real discount rate cost of funds (estimated at 5% of the cost of the repair) to do the repairs immediately upon the first indication of a leak rather than at a later date when the leak has gotten to the point of affecting the operation of the system. Other key assumptions including the assumed leak rate as well as the leak rate following repair are discussed in Appendix A.

- A new supermarket with a single large system with a total refrigerant charge of 3,000 pounds that combines all refrigeration and air-conditioning loads of the store.
- An older supermarket with four medium systems totaling 4,400 pounds of refrigerant to handle all refrigeration and air-conditioning loads of the store.
- A large office building with three chillers (one unit at 2,680 lbs charge, one unit at 2,120 lbs, and one unit at 750 lbs; 5,500 pounds total charge) to provide air conditioning.
- A small office building with a single small air-conditioning system with a total charge size of 100 pounds.

**Table 8:** Case study example costs

	Annual reporting and recordkeeping costs and system inspections / audits costs	Annual implementation fees	Annual monitoring system capital and operating costs	Expected annual repair costs *	Total gross annual costs	Annual refrigerant savings	Net annual costs	Cost-effective-ness (\$/MTCO <sub>2</sub> E)
New super-market with 1 large system (3,000 lbs total charge)	\$620	\$370	\$1,640	\$120	\$2,740	(\$1,210)	\$1,530	\$18
Older super-market with 4 medium systems (4,400 lbs total charge)	\$1,650	\$170	\$0	\$130	\$1,950	(\$1,130)	\$820	\$8
Large office building with 3 air conditioning systems (2 large and 1 small; 5,550 lbs total charge)	\$1,060	\$370	\$3,280	\$270	\$4,980	(\$2,710)	\$2,270	\$12
Small office building with 1 small air conditioning system (100 lbs total charge)	\$190	\$0	\$0	\$10	\$200	(\$60)	\$140	\$31

\* real discount rate cost of funds for making repairs immediately after identifying a leak rather than at a later date

## Economic Cost and Cost Savings Estimates (Refrigerant Sale, Use, and Disposal)

Refrigerant Use, Sale, and Disposal Cost and Economic Analysis - The cost and economic impacts specific to the Refrigerant Use, Sale, and Disposal component are based on requirements and prohibitions specific to California refrigeration and motor vehicle air conditioning (MVAC) and stationary heating, ventilation and air-conditioning (HVAC) service providers and refrigerant reclaimers, distributors, and wholesalers.

California Refrigeration and MVAC and Stationary HVAC Service Providers - The cost resulting from the refrigerant use, sale, and disposal component of the Refrigerant Management Program proposed rule are primarily borne by U.S. EPA certified technicians, refrigerant reclaimers, and refrigerant distributors or wholesalers.

California Service Contractors & Certified Technicians - As leak repairs are required to be completed by U.S. EPA certified technicians the certification cost to a technician related to a repair will be borne by a facility or the certified technician. Other than cost already identified for affected facilities, the primary requirements are related to evacuation of R/AC systems and recovery of refrigerant from empty cylinders, these costs are assumed to be borne by facilities for payments for refrigerant leak repair services. Equipment evacuation is already required by federal regulation for U.S. EPA certified technicians that provide refrigeration and air-conditioning service using ODS. Evacuation equipment, already required by federal rules for ODS system repairs, is already available and could be employed for recovery of all refrigerants. The proposed rule is not anticipated to result in additional costs for evacuation equipment.

California Refrigerant Reclaimers - Pursuant to Title 40 of the Code of Federal Regulation, Part 82, §82.154 refrigerant sales for ODS are limited to 1) sales to certified technicians, or their employer, 2) sales for the purpose of resale to certified technicians or appliance manufacturers, or 3) sales of refrigerant in an appliance. The proposed rule maintains the same requirements and extends the requirement to all high-GWP gases. The U.S. EPA estimated the annual burden of these requirements to total 8,882 hours. Many of the records required for the federal regulations would be required for all high-GWP gases as the refrigerant sales would be to the same certified technicians and appliance manufacturers. But, to be conservative if the ARB assumes the same burden and reduces the amount to reflect only California (~12%), the estimated burden would be 1,066 hours or approximately \$80,000 annually at \$75 per hour.

Based on federal regulations refrigerant reclaimers reclaiming ODS must maintain records of the names and addresses of persons sending them material for reclamation and the quantity of material sent to them for reclamation. This information must be maintained on a transactional basis. Pursuant to Title 40 of the Code of Federal Regulation, Part 82, §82.166, within 30 days of the end of the calendar year, reclaimers must report to the U.S. EPA the total quantity of material sent to them that year for reclamation, the mass of refrigerant reclaimed that year, and the mass of waste products generated that year. Reporting requirements in the proposed regulation in substantial part are already required by federal regulations for ODS. In the determination of costs for reclaimer reporting the U.S. EPA estimated that reporting required a total of five hours annually. At five hours and approximately 40 reclaimers in California additional reporting costs as a result of this rule are anticipated to be minimal at approximately \$15,000 per year.

California Refrigerant Distributors and Wholesalers - Based on federal regulations, Title 40 of the Code of Federal Regulation, Part 82, §82.166, refrigerant wholesalers who sell ODS refrigerants must retain invoices that indicate the name of the purchaser, the date of sale, and the quantity of refrigerant purchased. Although reporting is required under the proposed regulation, while it is not required by federal regulations, the reporting for distributors and wholesalers is a simple annual inventory report of the total refrigerant shipped to certified technicians and to reclaimers. The annual report would consist primarily of a summary of

recordkeeping required in significant part by federal regulations. Based on similar reporting requirements, using the U.S. EPA reclaimer reporting estimate of five hours annually and approximately 250 distributors in California additional reporting costs for the proposed annual report requirement are anticipated to be minimal at approximately \$94,000 per year.

## **Conclusion**

In summary, the refrigerant management rule will significantly reduce the emissions of high-GWP GHG, is technologically feasible, and at a cost-effectiveness of about \$8/MTCO<sub>2</sub>E and an average cost of approximately \$510 per facility per year.